Soret Effect on Free Convective Heat and Mass Transfer through a Porous Medium in a Vertical Channel

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Abstract

we made an attempt to analyze the soret effect on convective heat and mass transfer through a porous medium in a vertical channel. The dissipative effects are also taken in to account . Assuming Eckkert number much less than 1,the governing equations are solved and the velocity, temperature, concentration, shear stress and rate of heat and mass transfer are analyzed for various parameters.

Key words: *Heat and mass transfer, Porous medium, Soret effect.*

I. INTRODUCTION

Convective heat transfer in a porous medium has been the subject of intensive studies for the last few decades owing to its applications in different fields such as Chemical Engineering, Geothermal, Petroleum and Reservoir Engineering , Environmental protection ,thermal insulation cooling , Processing the food etc .The majority of the studies pertain to fluid flow and heat transfer in porous medium based on the Darcy flow model(5). Darcy's equation give satisfactory results for closely packed porous medium but does not explain the flow through sparsely distributed porous medium in later situation, Brinkman [3] proposed an alternate model by adding a term which accounts for the viscous shear in addition to the Darcy's equation .The first theoretical investigation of natural convection in a porous enclosure using Brinkman model was made by Chan et al [4] , Vafai and Tien [19], Vafai [18], Kim and Vafai [10]. They have worked on the problem of convective heat transfer in porous media relaxing some or all the limitations of Darcy's model . Later on ,a series of investigations were carried out using the Brinkman model by a few authors notably, Poulikakos and Bejan[13],Tong and Subramanian[17], Prasad and Tuntomo[14]. Forcheiner [7] extended Darcy model to the natural convection flow through porous medium.

Convection flows driven by temperature and concentration differences have been studied extensively in the past and various extensions of the problems have been reported in the literature[1],[9],[11],[15],[16],[20],[21] with both concentration and temperature interacting simultaneously, the convection can become quite complex .

Since many industrially and environmentally relevant fluids are not pure, it has been suggested that more attention should be paid to convective phenomena which can occur in mixtures, but are not present in common fluids such as air or water. Applications involving liquid mixtures include the casting of alloys, ground water pollutant migration and separation operations .In all of these situations multi-component liquids can undergo natural convection driven by buoyancy force resulting from simultaneous temperature and species gradients. In the case of binary mixtures, species gradients can be established by the applied solute boundary conditions such as species rejection associated with alloys casting or can be induced by coupled transport mechanisms such as Soret (thermo) diffusion. In the case of Soret diffusion, species gradients are established in an otherwise uniform concentration mixture in accordance with the onsager reciprocal relationships. Recently some importance has been attached to the Benard problem in a two component system in which an initially homogeneous mixture is subjected to a temperature gradient. Then thermal diffusion known as the Soret effect takes place and as a result a mass fraction distribution is established in the liquid layer. The sense of migration of the molecular species be determined by the sign of Soret coefficient .Keeping this view several authors have investigated the Soret effect under varied conditions [2],[6],[8],[12].

II. FORMULATION OF THE PROBLEM

We consider the flow of a viscous, incompressible fluid through a porous medium confined in a vertical channel bounded by two flat plates. We choose a rectangular cartesian coordinate system O(x ,y, z) with the plates in the x-y plane .The z-axis is taken normal to the plane of the plates .The walls are maintained at constant temperature T_1 & T_2 and constant concentrations C_1 & C_2 in the presence of constant heat sources of strength Q. All the field properties are assumed constant except that the influence of the density variation with the temperature and concentration is considered only in the body force term. The viscous dissipation and Darcy dissipation are taken into account. Also we take into consideration the thermal diffusion(Soret effect). A linear density variation is assumed with ρ_0 , T_0 & C_0 being the density, temperature and concentration of the fluid in the equilibrium state. The equations governing flow, heat and mass transfer in Cartesian coordinate O(x,y,z) in the non–dimensional form are

$$\frac{\partial^2 u}{\partial y^2} - D^{-1}u + G(\theta + Nc) = 0 \quad (1)$$

$$\frac{\partial^2 \theta}{\partial y^2} + Ec.\Pr\left[\left(\frac{\partial u}{\partial y}\right)^2\right] + Ec.\Pr D^{-1}u^2 + \alpha = 0 \quad (2)$$

$$\frac{\partial^2 C}{\partial y^2} + \left(\frac{S_c S_0}{N}\right)\frac{\partial^2 \theta}{\partial y^2} = 0 \quad (3)$$

where $G = \frac{\beta g(T_1 - T_0)h^3}{\nu^2}$ (Grashof number) $D^{-1} = \frac{h^2}{k}$ (Darcy number)

$P = \frac{\mu C_p}{k_1}$ (Prandtl number) $E_c = \frac{\nu^2}{h^2(T_1 - T_0)C_p}$ (Eckert number).

$\alpha = \frac{Qh^2}{k_1}$ (heat source parameter) $Sc = \frac{\nu}{D_1}$ (Schmidt number)

$S_0 = \frac{\beta^{\bullet} k_{11}}{\beta\nu}$ (Soret parameter)

The corresponding boundary conditions are

u = 0 on y = ±1

θ = 1 , C = 1 on y = -1 (4)

θ = -1 , C = -1 on y = 1

Assuming Ec(<<1) to be small, we take the asymptotic expansions of velocity , temperature and concentration as

$$u = u_0 + Ecu_1 + O(Ec^2)$$
$$\theta = \theta_0 + Ec\,\theta_1 + O(Ec^2) \quad (5)$$
$$C = C_0 + EcC_1 + O(Ec^2)$$

Substituting (5) in (1)-(3),the zeroth order equations are

$$\frac{\partial^2 u_0}{\partial y^2} - D^{-1}u_0 = -G(\theta_0 + NC_0) \quad (6)$$

$$\frac{\partial^2 \theta_0}{\partial y^2} + \alpha = 0 \quad (7)$$

$$\frac{\partial^2 C_0}{\partial y^2} + (ScS_o / N)\frac{\partial^2 \theta_0}{\partial y^2} = 0 \quad (8)$$

The respective boundary conditions are

$$u_0 = 0 \quad on \quad y = \pm 1$$
$$\theta_0 = 1\,,\ C_0 = 1 \quad on \quad y = -1$$
$$\theta_0 = -1\,,\ C_0 = -1 \quad on \quad y = 1 \quad (9)$$

The equations to the first order are

$$\frac{\partial^2 u_1}{\partial y^2} - D^{-1}u_1 = -G(\theta_1 + NC_1) \tag{10}$$

$$\frac{\partial^2 \theta_1}{\partial y^2} + P(\frac{\partial u_0}{\partial y})^2 + PD^{-1}u_0^2 = 0 \tag{11}$$

$$\frac{\partial^2 C_1}{\partial y^2} + (ScSo\ / N)\frac{\partial^2 \theta_1}{\partial y^2} = 0 \tag{12}$$

with the boundary conditions

$$u_1 = 0\ ,\theta_1 = 0, C_1 = 0 \qquad on \qquad y = \pm 1 \tag{13}$$

Solving the differential equations (6)-(8) and (10)-(12) with respective boundary conditions (9) and (13) we obtain

$$u_o = a_8 e^{h_1 y} + a_9 e^{-h_1 y} + a_5 y^2 + a_6 y + a_7$$

$$\theta_0 = \frac{\alpha}{2}(1 - y^2) - h$$

$$C_0 = a_1(y^2 - 1) - y$$

$$u_1 = a_{62} e^{h_1 y} + a_{63} e^{-h_1 y} + a_{42} Ch(2h_1 y) + a_{43} e^{-2h_1 y} + (a_{44} y^2 + a_{45} y + a_{46}) Sh(h_1 y)$$

$$+ (a_{47} y^3 + a_{48} y^2 + a_{4^4 9} y + a_{50}) Ch(h_1 y) + (a_{51} y^3 + a_{52} y^2 + a_{53} y + a_{54}) e^{-h_1 y}$$

$$+ a_{55} y^6 + a_{56} y^5 + a_{57} y^4 + a_{58} y^3 + a_{59} y^2 + a_{60} y + a_{61}$$

$$\theta_1 = a_{10} Ch(2h_1 y) + a_{11} e^{-2h_1 y} + (a_{12} y + a_{13}) Ch(h_1 y) + (a_{14} y^2 + a_{15} y + a_{16}) Sh(h_1 y)$$

$$+ (a_{17} y^2 + a_{18} y + a_{19}) e^{-h_1 y} + a_{20} y^4 + a_{21} y^3 + a_{22} y^2 + a_{23} y + a_{24}$$

$$C_1 = -\frac{ScS_o}{N}(a_{10} Ch(2h_1 y) + a_{11} e^{-2h_1 y} + (a_{12} y + a_{13}) Ch(h_1 y) + (a_{14} y^2 + a_{15} y$$

$$+ a_{16}) Sh(h_1 y) + (a_{17} y^2 + a_{18} y + a_{19}) e^{-h_1 y} + a_{20} y^4 + a_{21} y^3 + a_{22} y^2 + a_{23} y + a_{24}$$

Where the constants $a_1, a_2, \ldots\ldots, a_{63}$ are constants.

The shear stress on the plates are given by

$$\tau = \mu(\frac{\partial u}{\partial y})_{y=\pm h}$$

which in the non-dimensional form reduces to

$$(\tau)_{y=-1} = u_o^1(-1) + Ecu_1^1(-1)$$

$$= b_1 + Ecb_3$$

$$(\tau)_{y=1} = u_o^1(1) + Ecu_1^1(1)$$

$$= b_2 + Ecb_4$$

$$(\tau)_{y=-1} = u_o^1(-1) + Ecu_1^1(-1)$$

$$= b_1 + Ecb_3$$

and

the corresponding expressions are

$$(\tau)_{y=1} = u_o^1(1) + Ecu_1^1(1)$$

$$= b_2 + Ecb_4$$

where the constants b_1, b_2, b_3, b_4 are given in the Appendix.

From the temperature field, the rate of heat transfer coefficient in terms of Nusselt Number(Nu) is given by

$$Nu = \frac{q_w h}{K(T_1 - T_o)} = \left(\frac{\partial\theta}{\partial y}\right)_{y=\pm h}$$

$$= (\theta_o^1 + Ec\,\theta_1^1)_{y=\pm 1}$$

And the corresponding expressions are

$$(Nu)_{y=-1} = b_5 + Ecb_7$$

$$(Nu)_{y=1} = b_6 + Ecb_8$$

where the constants b_5, b_6, b_7, b_8 are constants.

The rate of mass transfer (Sherwood number) on the plates are given by

$$Sh = \left(\frac{\partial C}{\partial y}\right)_{y=\pm 1}$$

$$= (C_0^1 + Ec\,C_1^1)_{y=\pm 1}$$

and the corresponding expressions are

$$(Sh)_{y=-1} = b_9 + Ec\,b_{11}$$

and

$$(Sh)_{y=1} = b_{10} + Ec\,b_{12}$$

where the constants b_9, b_{10}, b_{11} and b_{12} are constants.

III. MATHEMATICAL MODEL AND VALIDATION

The set of partial differential equations (6)-(8) & (10)-(12) together with the boundary conditions (9) & (13) are numerically solved by employing perturbation technique. The following section, the results are discussed in detail with the aid of plotted graphs and tables. We made an attempt to discuss the flow of a viscous incompressible fluid, heat and mass transfer of the flow through a porous medium. In our numerical simulation the default values of the parameters are $G=2 \times 10^3$,$N=1$, $D^{-1}=10^3$, $\alpha=2$,$Sc=1.3$,$So=$. In order to analyze the effects of various parameters on velocity, temperature and concentration profiles, several graphs are plotted.

The profiles for velocity (u) for variation in the different governing parameters D^{-1},N,α,Sc & S_0 are presented in figs.(1)-(4). For all variations we find that the velocity gradually rises from its prescribed value at $y = -1$ to attain a maximum at $y = -0.6$ and then falls to its prescribed value at $y =1$. Lesser the permeability of the medium smaller the velocity in fluid region (fig.1). The effect of the molecular diffusivity on the velocity u shows that when Sc~0.24 we find an enhancement in u. For higher Sc~0.6 the velocity u fluctuates with maximum at $y = -0.6$ (fig.2). When the Soret parameter So increases through positive values the velocity is in upward direction and enhance with So. When So increases through negative values u changes from upwards to downwards as we move from the left boundary $y = -1$ to the right boundary $y =1$ and the maximum u is attained at $y = 0.4$(fig.3). In the presence of a heat source the velocity is upwards and is downwards in the case of a heat sink, We find that the magnitude of u enhances with increase in the intensity of either a heat source or a sink .In the case of a heat source maximum of u is attained at $y = - 0.6$ while in the case of heat sink the maximum occurs at $y = 0.6$(fig.4).

The temperature distribution (θ) for different variations of the parameters is exhibited in figs.(5)-(9). The temperature is positive or negative according as the actual temperature is greater or smaller than the mean temperature. We find that for variation in D^{-1}, So, $\alpha>0$, N & Sc we find that in the region $-1\leq y\leq 0.5$ the actual temperature is greater than the mean temperature while in the region $0.5<y\leq 1$ the actual temperature is less than the mean temperature. The variation of θ with Darcy parameter D^{-1} shows that the temperature decreases in magnitude with increase in $D^{-1}\leq 5x10^3$ but for higher $D^{-1}\geq 10^4$, $|\theta|$ enhances in the fluid region(fig.5).When the Soret parameter So increases through positive values we find a reduction in θ but for negative values of So we notice an enhancement in $|\theta|$(fig.6).Fig.7 shows the variation of θ with heat source parameter α .With an increase in the intensity of heat source we find an enhancement in $|\theta|$ with maximum attained at $y = -0.2$. In the case of heat sink the actual temperature is greater than the mean temperature in the region $-0.8 \leq y \leq -0.5$ while in the remaining fluid region the actual temperature is less than the mean temperature. $|\theta|$ enhances with the intensity of the heat sink. Maximum θ is attained at $y =0.2$. When the concentration buoyancy force dominates over the thermal buoyancy force the magnitude of the temperature decreases irrespective of the directions of the buoyancy forces (fig.9). Also we find that an increase in the molecular diffusivity decreases the temperature in the fluid region (fig.8).

The concentration distribution (C) is shown in figs.(10)-(12). As in the case of temperature the concentration in the fluid region is positive or negative according as the actual concentration is greater or lesser than the mean concentration. The magnitude of the concentration enhances with $D^{-1}\leq 5x10^3$ but for higher $D^{-1}\geq 10^4$ we find a depreciation in $|C|$ with maximum attained at $y = - 0.8$(fig.10).When the Soret parameter So increases through positive values we find an enhancement in $|C|$ with maximum at $y= - 0.4$ while for So increasing through negative values the actual concentration is less than the mean concentration with maximum at $y =0$.(fig.11).The variation of C with α shows that C is positive for $\alpha > 0$ and negative for $\alpha <0$ .The magnitude of the concentration enhances with increase in the intensity of a heat source or a sink(fig.12).

The shear stress (τ) on the boundaries is evaluated for different variations of G,D^{-1},N,α,Sc & So and are presented in tables.1-4.We find that the shear stress on the boundaries are almost negative except for $\alpha <0$.It is noticed that the stress on both the plates increase with increase in thermal buoyancy G.A decrease in the permeability of the porous medium reduces the magnitude of the shear stress on both the plates .At $y =1$ an increase in the intensity of the heat source reduces $|\tau|$ and increases it in the case of a heat sink .On the boundary $y = -1$ for $D^{-1} \leq 5x10^3$ the magnitude of the shear stress increases with $\alpha\leq 3$ but for higher $\alpha\geq 4$,$|\tau|$ enhances. For $D^{-1}\geq 10^4$, $|\tau|$ increases with all values of α while in the case of heat sink , $|\tau|$ increases with $|\alpha|(\alpha<0)$.When the concentration buoyancy dominates over the thermal buoyancy $|\tau|$ on both the boundaries increase when the forces act in the same direction , but when they act in opposing directions $|\tau|$ decreases with $|N|$ at the left boundary and increases it at the right boundary . As the Soret parameter So increases through negative values $|\tau|$ enhances on both the boundaries .When So increases through positive values, $|\tau|$ enhances with So for $D^{-1}\leq 5x10^3$

and for higher $D^{-1} \geq 10^4$, it increases with So at y =1 while | τ | on y = -1 decreases with |So| for all D^{-1}.Also an increase in the molecular diffusivity enhances |τ| on both the plates(tables.1&4).

The rate of heat transfer (Nusselt number) on the plates for different variations of the governing parameters are presented in tables.5-8.We find that on the plate y = 1 for $D^{-1} \leq 10^3$,the rate of heat transfer decreases with thermal buoyancy parameter G $\leq 3x10^3$ but for higher $G \geq 5x10^3$, |Nu| increases. For $D^{-1} \geq 3x10^3$ the rate of heat transfer increases with G while at y = -1 for $D^{-1} \leq 5x10^3$ it reduces with G but for $D^{-1} \geq 10^4$ it enhances with G.A decrease in the permeability of the porous medium reduces Nu on y =1 while on y =-1 , Nu decreases with $D^{-1} \leq 3x10^3$ and increases with $D^{-1} \geq 5x10^3$ .When the two buoyancy forces are in the same direction the rate of heat transfer on both the boundaries enhance with increase N .But when they are in opposing directions the magnitude of Nu reduces with |N |on y =1 and on y = -1 ,|Nu| reduces with N for $D^{-1} \leq 10^3$ while for $D^{-}1 \geq 3x10^3$ it increases with N .When the Soret parameter So increases through positive values the rate of heat transfer reduces with So while its magnitude enhances with So when it increases through negative values . An increase in the intensity of the heat source $\alpha \leq 5$,we find a depreciation in |Nu| for $D^{-1} \leq 3x10^3$,while for $D^{-}1 \geq 5x10^3$,|Nu| increases with $\alpha \geq 10$.In the case of heat sink we find that the magnitude of Nu enhances with |α| .Also an increase in the molecular diffusivity reduces |Nu| on the boundary y =1 and enhances it on the boundary y = -1 (tables.5-8).

The rate of mass flux(Sherwood number) on the boundaries are presented in tables. 9 - 12 for different variations in the governing parameters .We find that for $D^{-1} \leq 3x10^3$ the rate of mass transfer reduces with $G \leq 3x10^3$ and enhances with $G \geq 5x10^3$ while for $D^{-}1 \geq 5x10^3$ we find a reduction in the rate of mass flux on y =1 and an enhancement in it on y = -1 . A decrease in the permeability of the porous medium reduces Sh on both the boundaries while |Sh| decreases with $D^{-1} \leq 3x10^3$ and increases with $D^{-1} \geq 10^3$. When the buoyancy forces act in the same directions the rate of mass transfer reduces with N at y =1 and enhances at y = -1 but when they are in opposing directions Sh reduces with N . An increase in the intensity of the heat source increases Sh at y = 1 and at y =-1 it decreases with $\alpha \leq 5$ and increases with $\alpha \geq 10$.A reversed effect is observed in the case of heat sink .The variation of Sh with So shows that an increase in So enhances Sh .Also an increase in the molecular diffusivity reduces the magnitude of Sh at y =1 and increases it on y =-1.

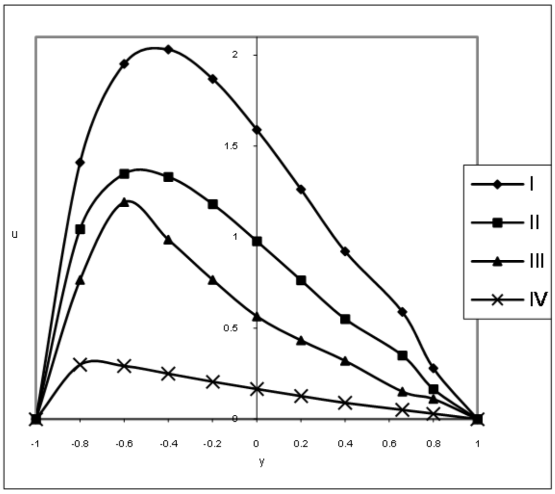

Fig.1 u with D^{-1}
$G=10^3$, N=1,Sc=1.3,So=0.5, $\alpha=2$

	I	II	III	IV
D-1	$3x10^3$	$5x10^3$	10^4	$2x10^4$

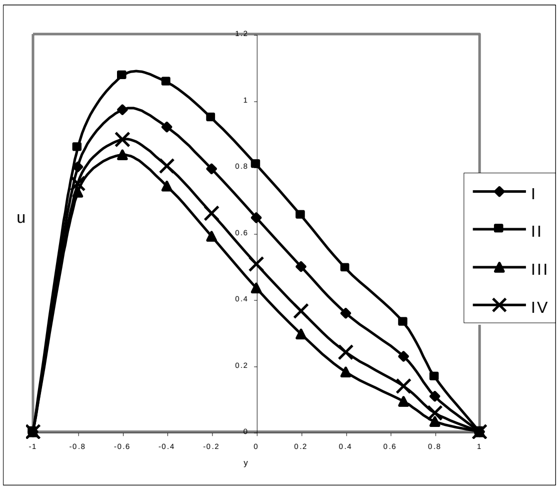

Fig.2 Variation of u with Sc
$D^{-1}=10^3$,$G=10^3$,N=1,So=0.5

	I	II	III	IV
Sc	1.3	2.01	0.24	0.6

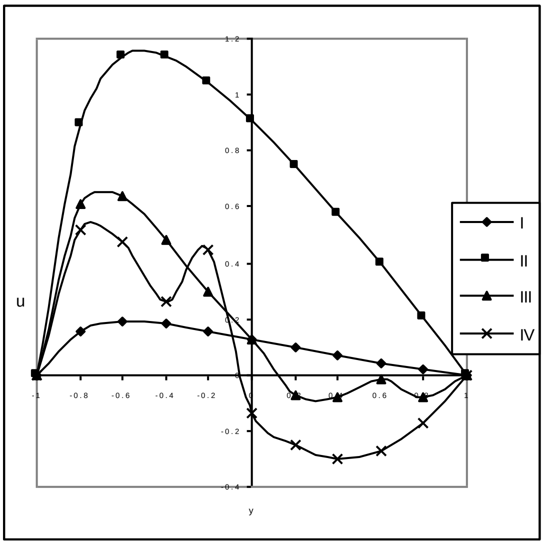

Fig.3 u with So

G= 10^3 , D^{-1} =10^3,Sc=1.3,N=1, α=2

	I	II	III	IV
So	0.5	1	-0.5	-1.0

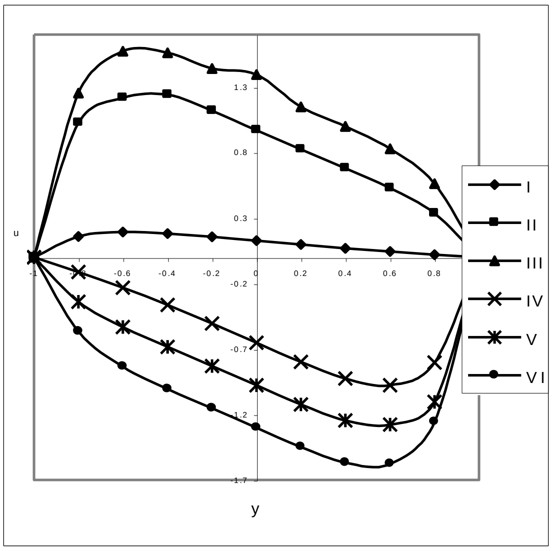

Fig4 u with α

G=10^3 , D^{-1} =10^3,Sc=1.3,N=1, α=2

	I	II	III	IV	V	VI
α	2	5	10	-2	-5	-10

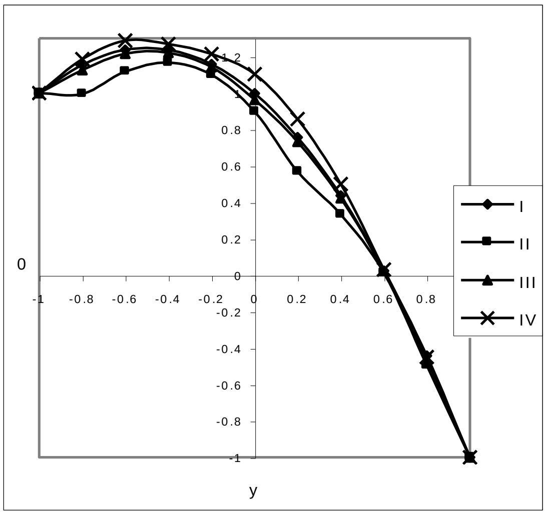

Fig.5 θ with D^{-1}

G = 10^3, N=1,Sc=1.3, So=0.5,α=2

	I	II	III	IV
D^{-1}	$3x10^3$	$5x10^3$	10^4	$2x10^4$

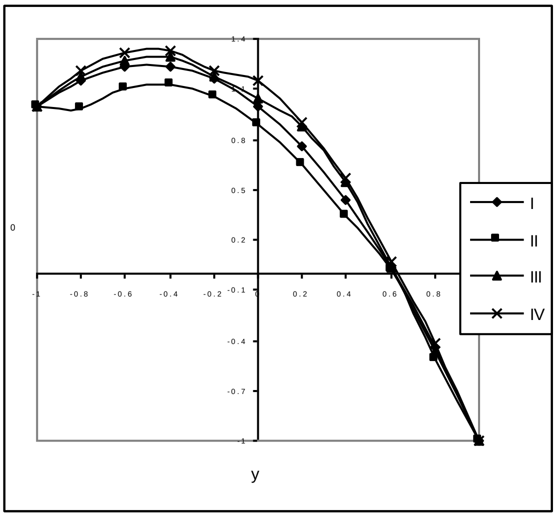

Fig.6 θ with So

	I	II	III	IV
So	0.5	1.0	-0.5	-1.0

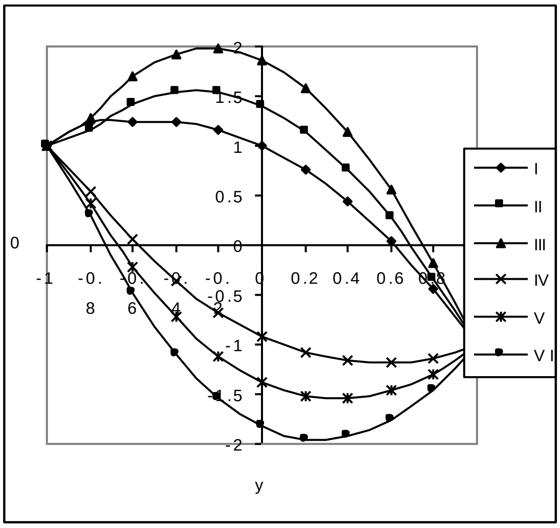

Fig.7 θ with α

	I	II	III	IV	V	VI
α	2	5	10	-2	-5	-10

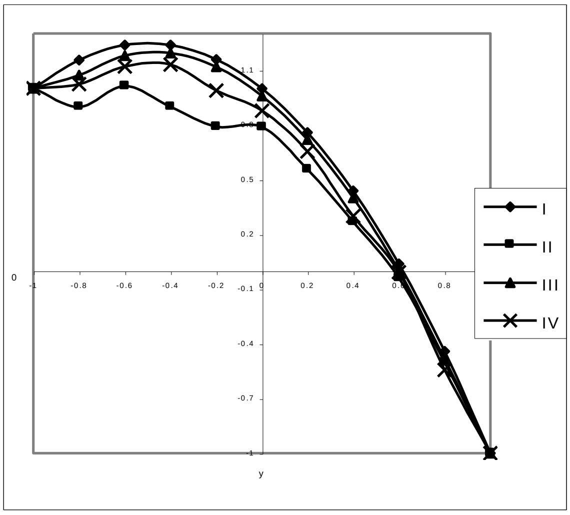

Fig.8 θ with Sc

	I	II	III	IV
Sc	1.3	2.01	0.24	0.6

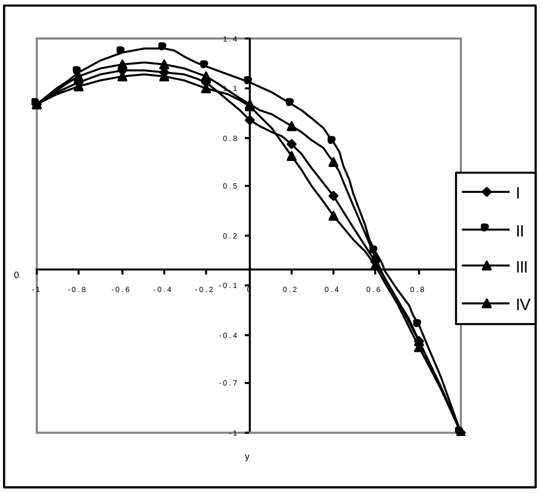

Fig.9 θ with N

	I	II	III	IV
N	1	-0.5	2	-0.8

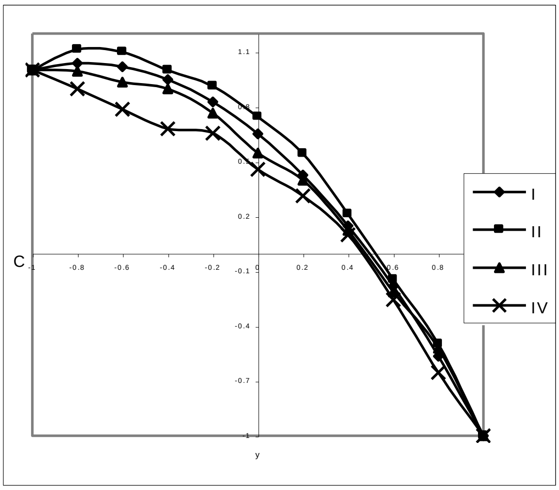

Fig.10 C with D^{-1}

$G=10^3, N=1, Sc=1.3, So=1.5$

	I	II	III	IV
D^{-1}	$3x10^3$	$5x10^3$	10^4	$2x10^4$

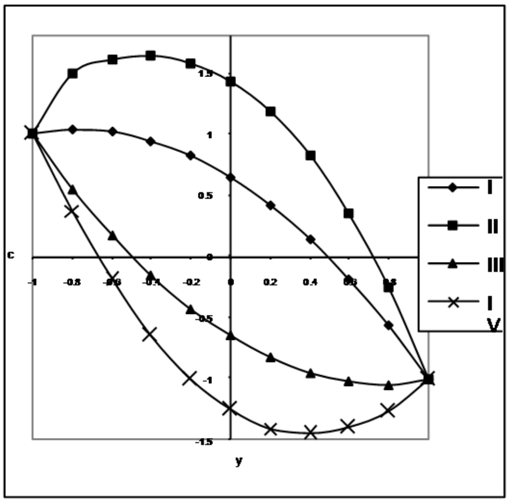

Fig.11 C with So
G $=10^3$, $D^{-1}=10^4$, N=1,Sc=1.3

	I	II	III	IV
Sc	0.5	1.0	-0.5	-1.0

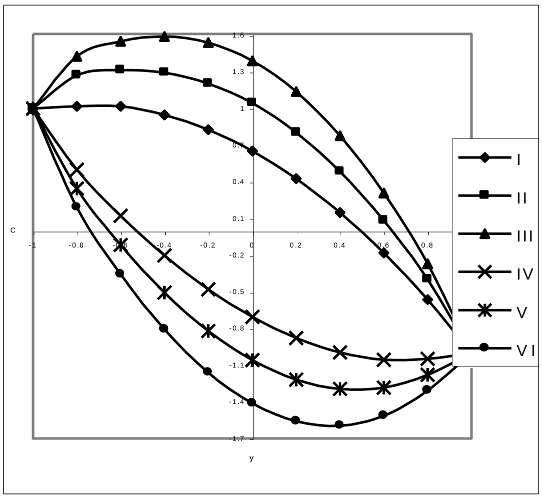

Fig.12 C with α

	I	II	III	IV	V	VI
α	2	5	10	-2	-5	-10

Table.1
Shear stress (τ) at y=1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	0.5399	2.5674	15.898	2.3661	.5038	0.1183	0.6012	-1.436	-.5604
$3x10^3$	-.0549	-.2254	-2.135	-.4437	.0612	.0007	-.0087	.2839	.1282
$5x10^3$	-.0201	-.0372	-.2455	-.0978	.0419	.0023	-.0065	.1012	.0451
10^4	-.0199	-.0307	-.0315	-.0236	.0323	.0006	-.0045	.0225	.0089
$2x10^4$	-.0253	-.0496	-.0871	-.0197	.0284	-.0015	-.0021	-.0176	-.0252

Table.2
Shear Stress (τ) at y = - 1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-13.713	-15.927	-24.354	-15.544	1.1961	-1.431	-5.038	-17.981	-16.625
$3x10^3$	-6.4813	-9.805	-16.954	-9.346	0.0377	-0.937	-1.979	-8.776	-8.385
$5x10^3$	-2.4813	-7.008	-9.301	-5.464	-0.1851	-0.574	0.4114	-4.977	-4.341
10^4	2.4404	-4.199	-2.048	-3.0327	-0.1411	-0.299	2.0041	-3.165	-2.335
$2x10^4$	1.5315	1.4182	5.2084	-0.3618	0.1308	0.1292	3.6895	-1.4708	-0.472

G	$2x10^3$	$3x10^3$	$5x10^3$	$2x10^3$	$2x10^3$	$2x10^3$	$2x10^3$	$2x10^3$	$2x10^3$
N	1	1	1	2	-.5	-.8	1	1	1
Sc	1.3	1.3	1.3	1.3	1.3	1.3	2.01	0.24	0.6

Table.3
Shear Stress (τ) at y = 1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-3.582	0.0565	8.1739	0.5399	-.0782	0.7271	-8.137	-9.819	-7.348
$3x10^3$	0.6854	0.0298	-1.588	-.0594	-.0151	.1422	-9.238	11.181	14.756
$5x10^3$	0.2442	0.0340	-0.562	-.0202	-.0159	.1599	5.1483	9.656	11.238
10^4	0.0849	0.0404	-.2015	-.0201	-.0134	.1484	2.3181	5.838	8.327
$2x10^4$	-.201	0.0497	-.0631	-.0253	-.0115	.1299	1.2359	3.092	5.531

Table.4
Shear Stress (τ) at y = -1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-8.378	6.093	11.338	-13.713	-17.744	-11.558	68.123	98.569	112.145
$3x10^3$	-7.453	3.414	-.0285	-6.253	-5.734	1.672	52.321	82.468	92.126
$5x10^3$	-5.957	3.731	-5.698	-2.482	0.531	6.652	30.608	49.579	72.831
10^4	-6.021	4.499	-8.251	2.441	2.483	8.533	20.338	33.591	50.067
$2x10^4$	-6.701	5.619	-9.515	1.532	4.318	9.212	11.696	19.554	29.543

S_0	-.05	1	-1	0.5	0.5	0.5	0.5	0.5	0.5
α	2	2	2	2	5	10	-2	-5	-10

Table.5

Nusselt Number (Nu) at y = 1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-32.684	-3.029	-52.44	-35.02	-89.739	-65.114	-3.419	-79.679	-45.958
$3x10^3$	-4.058	-5.517	-10.49	-4.855	-3.601	-3.239	-3.488	-5.068	-4.704
$5x10^3$	-3.273	-3.611	-4.699	-3.532	-3.096	-3.026	-3.054	-3.6154	-3.4967
10^4	-3.165	-3.366	-4.007	-3.343	-3.056	-2.998	-3.015	-3.393	-3.315

Table.6

Nusselt Number (Nu) at y = -1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	19.5503	1.0634	-13.29	37.1287	38.3636	23.7567	36.238	-2.059	2.1934
$3x10^3$	0.7957	0.5115	-0.4798	0.9888	0.8181	0.9599	1.4549	-0.0288	0.2297
$5x10^3$	1.0346	1.0412	1.0163	1.2809	0.9269	0.9866	1.2262	0.7647	0.8542
10^4	1.0479	1.0848	1.1772	1.2601	0.9551	0.9977	1.1615	0.8816	0.9377

G	$2x10^3$	$3x10^3$	$5x10^3$	$2x10^3$	$2x10^3$	$2x10^3$	$2x10^3$	$2x10^3$	$2x10^3$
N	1	1	1	2	-.5	-.8	1	1	1
Sc	1.3	1.3	1.3	1.3	1.3	1.3	2.01	0.24	0.6

Table.7

Nusselt Number (Nu) at y = 1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-32.685	-55.004	19.548	-87.091	-21.091	-21.162	-12.847	1.047	18.514
$3x10^3$	-4.058	-6.8767	-3.079	-8.721	-5.598	-7.381	-0.3126	0.0197	0.1105
$5x10^3$	-3.273	-4.147	-2.8799	-4.627	-4.412	-5.641	0.3753	1.0609	1.656
10^4	-3.165	-3.731	-2.8912	-4.022	-4.246	-5.387	0.5461	1.3211	2.0347

Table.8

Nusselt Number (Nu) at y = -1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	19.551	-26.4058	51.4558	-40.4566	0.8943	-0.9451	61.1645	76.5728	86.2831
$3x10^3$	0.7956	-0.8854	2.0681	-2.2941	1.4241	1.9545	-2.7001	-3.8194	-5.0369
$5x10^3$	1.0346	0.4073	1.3921	0.1376	1.7679	2.3462	-3.4496	-4.9583	-6.6221
10^4	1.0479	0.6473	1.2573	0.4561	1.8468	2.5276	-3.3301	-4.7203	-6.2286

S_0	-.05	1	-1	0.5	0.5	0.5	0.5	0.5	0.5
α	2	2	2	2	5	10	-2	-5	-10

Table.9

Sherwood Number (Sh) at y = 1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	16.995	15.641	29.837	8.754	-35.546	-25.905	-2.588	7.9616	16.482
$3x10^3$	-1.612	-.6639	2.569	-1.047	.8189	.4303	-2.519	-.992	-1.088
$5x10^3$	-2.122	-1.902	-1.197	-1.477	1.477	.6035	-2.955	-1.166	-1.451

10^4	-2.192	-2.062	-1.645	-1.538	1.527	-.9751	-2.961	-1.193	-1.505

Table.10
Sherwood Number (Sh) at y = -1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-11.758	-2.898	9.589	-12.092	-12.973	10.865	-14.401	-.3928	-1.551
$3x10^3$	.4328	.6175	1.262	-.3464	-3.836	-2.657	.5528	-.6365	-.1689
$5x10^3$	.2775	.2732	.2894	-.4413	-3.695	-2.636	.7827	-.7318	-.3563
10^4	.2688	.2448	.1848	-.4345	-3.658	-1.016	.8476	-.7458	-.3813

G	$2x10^3$	$3x10^3$	$5x10^3$	$2x10^3$	$2x10^3$	$2x10^3$	$2x10^3$	$2x10^3$	$2x10^3$
N	1	1	1	2	-.5	-.8	1	1	1
Sc	1.3	1.3	1.3	1.3	1.3	1.3	2.01	0.24	0.6

Table.11
Sherwood Number (Sh) at y = 1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	16.995	-19.503	-12,913	-35.712	13.123	6.905	9.311	1.569	-8.484
$3x10^3$	-1.612	-2.221	-3.496	-5.837	-1.911	-2.053	1.153	2.237	3.478
$5x10^3$	-2.122	-1.123	-3.756	-.5154	-2.683	-3.184	.7061	1.561	2.474
10^4	-2.193	-.1745	-3.741	.2717	-2.791	-3.348	.5951	1.391	2.228

Table.12
Sherwood Number (Sh) at y = -1

D^{-1}	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-11.758	-20.116	-19.399	-26.494	0.5263	4.164	-36.736	-45.287	-56.671
$3x10^3$	.4328	-3.525	.2114	-6.582	1.325	2.278	-2.495	-3.069	-3.576
$5x10^3$	.2775	-2.995	1.091	-4.721	1.102	2.025	-2.007	-2.327	-2.546
10^4	.2688	-2.529	1.265	-4.307	1.049	1.907	-2.085	-2.482	-2.802

S_0	-.05	1	-1	0.5	0.5	0.5	0.5	0.5	0.5
α	2	2	2	2	5	10	-2	-5	-10

IV. CONCLUSIONS

The soret effect on convective heat and mass transfer flow of viscous incompressible fluid through a porous medium in a vertical channel have been analysed.For all variations we find that the velocity gradually rises from its prescribed value at y = - 1 to attain a maximum at y = -0.6 and then falls to its prescribed value at y =1. The temperature and concentration is positive or negative according as the actual temperature or concentration is greater or smaller than the mean temperature and concentration respectively. We find that the shear stress on the boundaries are almost negative except for α <0. The rate of heat transfer decreases with lower permeability and enhances with higher permeability for various parameters while Sherwood number reduces at the plate y=1 and enhances at y=-1 for various parameters.

REFERENCES

[1] Angirasa,D., Peterson,G.P and Pop,I : Combined heat and mass transfer by natural convection with opposing buoyancy effects in a fluid saturated porous medium., Int.J.Heat Mass transfer, V.40, No.12, pp.2755-2733, 1997.
[2] Bergman,T.L and Srinivasan,R : Int.J.Heat Mass Transfer,V.32,pp.679-687, 1989.
[3] Brinkman,H.C : A calculation of the viscous force exerted by a flowing fluidon a dense swan of particles,Appl.Sci .Res,A1, pp-81, 1948
[4] Chan,B.K.C.,Ivery,C.M and Barry,J.M : Natural convection in enclosed porous media with rectangular boundaries,ASME,Journal of Heat Transfer, V.2, pp.21-27, 1970.
[5] Darcy,H : Les Fountaines published de la ville de Dijon victor dalmont,Paris,1956
[6] David Jacqmin : Parallel flows with Soret effect in tilted cylinders,J.Fluid Mech., V.211, pp.355-372,1990.
[7] Forcheiner,P : Wasserbewegung durch Boden,Forsch.Ver.D,Ing, V.45,pp.1782, 1901.
[8] Hari Mohan :The Soret effect on the rotatory thermosolutal convection of the veronis type,Ind.J.Pure and Appl.Math. V.26, pp.609-619, 1996.
[9] Jang ,J. Y and Chang,W.J : The flow and vortex instability of horizontal natural convection in a porous medium resulting from combined heat and mass buoyancy effects., Int.J.Heat Mass transfer, V.31, pp.769-777, 1988.
[10] Kim,S.J and Vafai,K : Analysis of natural convection about a vertical plate embedded in a porous medium, Int . J. Heat Mass Transfer,V.32, No.4, pp.665-677, 1989.

[11] Lai,F.C : Coupled heat and mass transfer by natural convection from vertical plate in saturated porous medium., Int.Comm.Heat Mass Transfer, V.18, pp.93-106, 1991.

[12] Malasetty, M.S and Gaikwad, S.N :Effect of cross diffusion on double diffusive convection in the presence of horizontal gradients.,Int.J.Engng., V.40, pp.773-7872002,.

[13] Poulikakos,D and Bejan,A : The non-Darcy regime for vertical boundary layer natural convection in a porous medium,Int.J.Heat Mass Transfer, V.27, pp.717-722, 1984.

[14] Prasad,V and Tuntomo,A : Integral effects on natural convection in a vertical porous cavity ,Num.Heat Transfer, V.11, pp.295-320, 1987.

[15] Raptis,A and Perdikis,C : Mass transfer and free convection flow through a porous medium, Energy Reasearch,V.11,pp.423-428,1987.

[16] Schroppel,J and Thiele,T.F : On calculation of momentum heat and mass transfer in laminar and turbulent boundary layer flows along a vapourising liquid film,Numerical Heat Transfer, 1983, V.6, pp.475-496,1987.

[17] Tong,T.W and Subramanian ,E : Boundary layer analysis for natural convection for vertical porous enclosure-use of Brinkman model.,Int.J.Heat and Mass Transfer,V.28,pp.563-571,1985.

[18] Vafai,K : Convective flow and heat transfer in variable porosity media,J.Fluid.Mech.,V.147, pp.233-259,1984.

[19] Vafai,K and Tien,C.L : Boundary and Inertial effects on flow and heat transfer in porous media , Int. J. Heat Mass Transfer, V.24 , pp.195-203, 1989.

[20] Yan,W.M : Turbulent mixed convection heat and mass transfer in a wetted channels, ASME-Jourrnal of Heat Transfer, V.117, pp.229-233, 1995.

[21] Yih,K.A : Coupled heat and mass transfer in mixed convection over a wedge with variable wall temperature and concentration in porous media,The entire Regime, Int. Comm. Heat Mass Transfer., V.25, pp.1145-1158, 1998.